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Challenges for energy efficiency improvement under the CDM—the case of energy-efficient lighting

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Abstract The CDM under the Kyoto Protocol has so far been unable to mobilize activities of households and service industries to improve end-use energy efficiency. This is mainly due to the lack of or the cumbersome requirements of the few existing baseline and monitoring methodologies as well as the difficulty to prove project additionality. We assess methodologies for projects distributing compact fluorescent lamps to households. The approval of the first large-scale methodology took more than 2 years and in the interaction with the regulatory bodies, the methodology became very cumbersome, especially regarding monitoring requirements. Four sample groups are required and the technology that has to be used for measuring utilization of CFLs does not yet exist. Therefore, project developers are not applying the large-scale methodology but try to use the pre-defined small-scale methodology. But even the small-scale methodology requires a substantial amount of data and measurements. A "Programme of Activity" approach could reduce monitoring costs through limiting monitoring to a sample of projects. Moreover, monitoring experts could be trained and thus monitoring mistakes reduced compared to single project settings. A deemed savings methodology was recently approved which alleviates but does not completely eliminate monitoring needs. It considerably reduces CER volumes compared to the other two methodologies and thus project developers have to assess the trade-off between higher monitoring costs and lower CER volumes.

Keywords CDM · Climate policy · End-use energy efficiency · CFLs · Baseline · Monitoring · Methodologies

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Introduction into the CDM and the methodology procedure

Market mechanisms in international climate policy

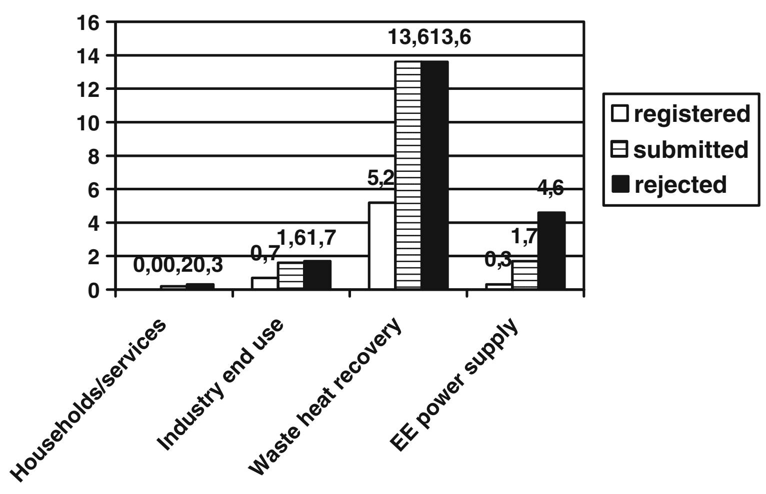
The Clean Development Mechanism (CDM) allows industrialized countries to generate emissions credits (certified emission reductions, CERs) through emission reduction projects in developing countries. CERs can be used to achieve compliance with the emissions targets specified in the Kyoto Protocol. As developing countries do not have any emissions targets, an elaborate body of rules and supervisory institutions has been set up to ensure that CERs reflect "real, measurable and long-term" emission reductions (Art. 12, 5b Kyoto Protocol).

As Gupta et al. (2007) show, market mechanisms have recently seen an important upswing in national and international climate policy. They state that "the Kyoto Protocol's most notable achievements are the stimulation of an array of national policies, the creation of a carbon market and the establishment of new institutional mechanisms. [...] The Clean Development Mechanism (CDM), in particular, has created a large project pipeline and mobilized substantial financial resources, but it has faced methodological challenges in terms of determining baselines and additionality" (Gupta et al. 2007, p. 748). These methodological challenges have been particularly pronounced for energy efficiency projects (see Arquit Niederberger 2008). While according to the IPCC 4th Assessment Report, the role of energy efficiency is important in almost all sectors of the economy and takes up the lion's share in the reduction potential of key sectors such as industry and buildings (see Barker et al. 2007), currently energy efficiency is only having a minor share of the projected CER volume by 2012 (see Fig. 1).

Only waste heat recovery projects in heavy industry have managed to achieve a sizeable share of submitted projects but still fall far short from the potential of energy efficiency in heavy industry in general (see Hayashi and Krey 2007 for an estimate of that potential). Projects improving energy efficiency in buildings so far have a negligible share of less than 0.1%, despite having the highest emission reduction potential of all sectors of the economy (see Levine et al. 2007). Besides the methodological challenges described in this article, the dispersed nature of end-use energy efficiency projects and their generally small size leads to high transaction costs of the CDM project cycle, as many elements of these transaction costs have a fixed character (see Michaelowa and Jotzo 2005). Moreover, the determination of additionality (see below) is more difficult for energy efficiency projects than classical CDM projects due to the fact that many projects are very profitable but still not implemented. While the CDM rules allow to show that non-monetary barriers prevent a project with very attractive financial parameters, the CDM regulators are no longer accepting barrier arguments due to misuse of the barrier test by several project developers.

A general assessment of the challenges that energy efficiency projects face with regards to the approval and application of baseline methodologies has been done by Hayashi and Michaelowa (2007) and Müller-Pelzer and Michaelowa (2005). We want to complement this analysis by a detailed case study of projects disseminating compact fluorescent lighting, as we collected a sizeable amount of experience in developing and applying methodologies for this project type. We think

Fig. 1 Share of energy efficiency projects in total expected CER volume by 2012 (%)



Data source: URC (2008)

that this case study exemplifies the challenges of end-use energy efficiency under the CDM.

Principles of baseline and monitoring methodologies

While the CDM was agreed in principle in 1997, it took 4 years to agree on detailed rules, which was achieved in the Marrakech Accords of late 2001 (UNFCCC 2005b). A cornerstone of these rules is the specification of methodologies to calculate baseline emissions and to monitor emissions reductions.

A baseline methodology wants to determine the emissions level that would have occurred in the absence of the CDM project. As this "counterfactual" is hypothetical, a series of principles has to be developed to enable a consistent baseline setting. The starting point is the concept of "additionality". A project is additional if it would not have happened in the absence of the incentive provided by the CDM. This interpretation has been contested right from the start. Business representatives have argued that it is impossible to determine why a project developer embarks on a project. Therefore, they would like to declare any project additional whose emissions are below the emissions of the project (see Rentz 1998). On the other hand, environmental NGOs wanted to declare all projects non-additional that are profitable without CER revenue (Greenpeace International, 1998). The Marrakech Accords (UNFCCC 2005b, para 43ff) define the basic ideas of baseline determination, while they do not provide an operationalization of the additionality concept and just repeat the additionality principle of Article 12, 5 (c) of the Kyoto Protocol. A "baseline" is defined as "scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gasses that would occur in the absence of the proposed project activity".[1] Baselines have to be project-specific and defined in a way that CERs cannot be earned for decreases in activity levels outside the project activity or due to force majeure. Relevant national policies and circumstances and current practices in the host country or region as well as least-cost technology for the project type are to be taken into account. Three principal approaches are available for defining a baseline methodology (UNFCCC 2005b, para 48 a–c):

– Existing actual or historical emissions, as applicable
– Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment
– The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental, and technological circumstances, and whose performance is among the top 20% of their category

Over time, a set of principles has emerged that guides methodology development. The Marrakech Accords defined the concept of project boundary as "all anthropogenic emissions by sources of greenhouse gasses under the control of the project participants that are significant and reasonably attributable to the CDM project" (UNFCCC 2005b, para 52). On this basis, leakage is defined as "net change of anthropogenic emissions by sources of greenhouse gasses which occurs outside the project boundary, and which is measurable and attributable to the CDM project" (ibid., para 51). Leakage shall be deducted from the emission reductions calculated against the baseline. Baselines have to be transparent and conservative and take into account uncertainty. Consistency, predictability and rigor are necessary to ensure that emissions reductions are "real and measurable and an accurate reflection of what has occurred within the project boundary". Baseline methodologies have to address additionality determination and shall "reasonably represent what would have occurred in the absence of a project activity" (see UNFCCC 2005b, Appendix C to decision 3/CMP.1 "Terms of reference for establishing guidelines on baselines and monitoring methodologies"), if possible by an appropriate level of standardization. Monitoring methodologies are to provide an "accurate measurement of actual reductions [...] taking into account the need for consistency and cost effectiveness" (ibid.). Documentation of monitoring has to be complete. Regarding accuracy, the EB has been very strict, requiring very costly measurement equipment. For example, it took two years for project developers of methane destruction projects to get rid of the requirement to measure the methane content of the

[1] This is derived from the principle of "real...measurable...long-term" reductions in Article 12, 5 (b) of the Kyoto Protocol.

flare exhaust gas, which is technically difficult and costly. The developers had to accept a heavy discount regarding the efficiency of the flare if no measurements are taken.

The challenge of methodology development

Baseline and monitoring methodologies[2] are developed in a "bottom-up" fashion. For each project type, a pioneering CDM project developer has to submit a methodology proposal to the Methodology Panel (MP) of the CDM Executive Board (EB). The submitted methodology is sent to two experts who provide a desk review. On the basis of this review, the MP makes a recommendation to the EB whether the methodology can be approved, should be revised, or has to be rejected. The EB generally follows this recommendation but there have been famous cases of methodologies being sent back to the MP for improvement. The process has been changed several times, with an increasing emphasis on inputs from the UNFCCC Secretariat. This is due to the fact that the EB was able to hire a large number of support staff from late 2006.

The first methodologies were submitted in early 2003; since then over 250 methodologies have been proposed in over 20 submission rounds. More than half of the submitted methodologies have been rejected, making methodology development a risky business. Despite 5 years of experience with methodology development, rejection rates have not come down (see Fig. 2).

Even consultants that have collected substantial experience with methodology development have not been able to beat the average performance rate. Figure 3 shows that only three out of the 12 consultants with more than five methodology submissions have had a success rate of over 50%.

When the MP and EB started to realize that methodologies were submitted for very similar project types, they started a consolidation drive. In mid-2004, the first consolidated methodology was approved for landfill gas collection. Until October 2008, 15 consolidated methodologies had been introduced and 13 previously approved methodologies withdrawn that are now covered by a consolidated one.

For so-called small-scale projects,[3] the EB provided a set of 12 methodologies in early 2003. These methodologies played an important role as precedents on which methodology submissions by project developers were based. However, many elements of them need interpretation as they have not been specified in sufficient detail to be applied "off the shelf". From time to time, the EB added a new methodology. In 2005, project developers started to realize that submission of a small-scale methodology for a difficult project type was having a much higher chance of success than a large-scale methodology. This was due to the inability of the Small-Scale Working Group (SSC-WG) to reject methodologies except in cases where the project type suggested was clearly non-eligible for CDM. When over 20 methodologies had been submitted and a process of endless revision had started for some of those submissions that were of low quality, in late 2007 the EB decided an alignment of the small-scale methodology submission procedures with the large-scale ones. This allows rejections and therefore has closed the "easy path". By October 2008, 38 small-scale methodologies had been approved

Overall, private project developers have been reluctant to invest a lot of money in development of methodologies that are likely to be rejected and that become a public good once approved. This incentive problem has been somewhat alleviated by the willingness of multilateral development banks, CDM consultants and governments to finance methodology development.

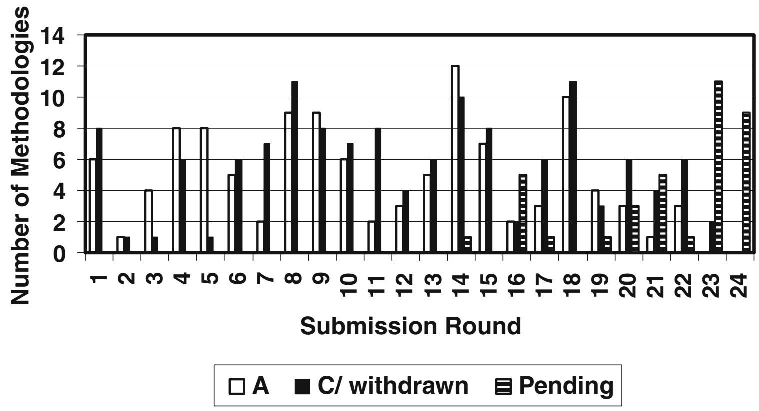
CDM methodologies and energy efficiency—general challenges

When looking at the approved methodologies for energy efficiency two main categories can be differentiated. On the one hand, methodologies for supply side energy efficiency like efficient power generation technologies (e.g., ACM00013) or fuel switching

[2] Initially, it was thought that baseline setting and monitoring could be separated. It however became clear quickly that monitoring requirements are so dependent on the specification of the baseline that from 2006 onwards, baseline and monitoring methodologies were linked.

[3] From 2001 to 2005, these were projects of less than 15 MW for renewable energy, 15 GWh annual savings for energy efficiency and direct emissions of 15,000 t CO_2 equivalent for other project types. In 2005, the thresholds were changed to 60 GWh for energy efficiency and 60,000 t CO_2 equivalent for other project types.

Fig. 2 Methodology rejection over time



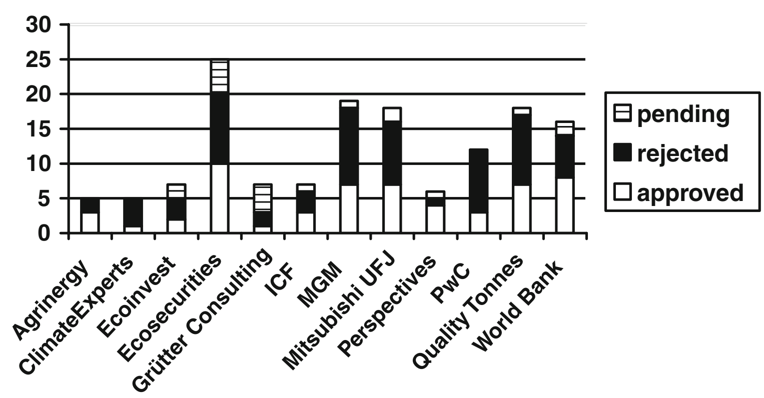
A= approved, C= rejected
Source: URC (2008)

mainly related to energy supply, on the other hand, methodologies for demand side energy efficiency. Here, the majority of the approved methodologies concentrate on industrial processes like aluminum production or oil refinery processes. To date, projects applying demand side energy-efficient technologies for domestic end users are rather underrepresented in the CDM. This can be explained by high hurdles for methodology approval. If one looks at the rejection statistics differentiated according to project types, one sees that energy efficiency methodologies for end users have significantly higher rejection rates than the average methodology (see Fig. 4). Moreover, only very few methodologies for demand side management have been submitted.

What are the reasons for these high methodology rejection rates? An analysis of 43 energy efficiency methodologies submitted before 2005 showed that most methodologies were rejected because they did not comply with quality standards regarding presentation and conservativeness (Müller-Pelzer and Michaelowa 2005). Tools to select the baseline scenario and to prove additionality were frequently lacking. Black box models were not accepted. The remaining lifetime of equipment and autonomous energy efficiency improvement through penetration of the technology used in the project even in the absence of the project were not taken into account.

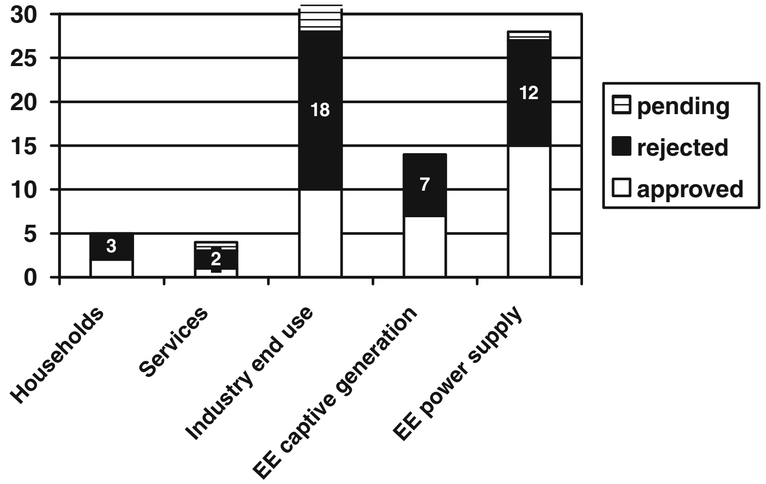
Methodology submitters learned from the early rejections. Their main strategy was to take elements of small-scale methodologies as the starting point for new submissions. Regarding technical lifetime independent information on industry practices or documented practices of replacement by the project

Fig. 3 Success rate of key methodology developers



Source: Data from URC (2008); only developers with more than 5 methodologies are covered

Fig. 4 Rejections and approvals for energy efficiency methodologies



Data source: URC (2008)

developer have been accepted (see small-scale methodology AMS II.C). However, new problems surfaced that were difficult to overcome: monitoring many dispersed appliances, addressing rebound effects and assessing interaction between multiple measures. Spalding-Fecher (2008) stresses the problem of signal-to-noise ratio, i.e., how to distinguishing exogenous factors from the effect of the project and to account for changes in output mix, service levels or system characteristics. Successful methodologies have either applied narrow applicability conditions prohibiting change in output and load factors, adjusted for changes in operating conditions or used control groups. Modeling approaches have not yet been accepted.

To show the challenges that remain even if methodologies are approved, we analyze the cases of three methodologies for energy-efficient lighting in the following sections. The development of these methodologies did not happen in isolation but in close interaction; for example the deemed savings methodology (Section 5) was developed due to the perception that the first approved methodology (Section 3) could not be used in practice. The analysis focuses on the changes of the methodologies during the approval process as well as the difficulties in applying the approved methodologies.

Challenges in developing CFL methodologies

Theoretically, one could assume that the bottom-up process of CDM methodology development guarantees that a methodology is developed that takes into account the requirements of the methodology developer. However, in reality, this is not the case due to the structure of the regulatory process. We go into some detail to show how a methodology becomes "alienated" from its developer—and therefore unusable—through a series of interactions between the EB/MP and the methodology developer.[4]

The first end-use energy efficiency methodology is methodology AM 0046 for distribution of compact fluorescent lamps to households. It took from 2004 to 2006 for the CDM consultancy Perspectives to get this methodology approved.[5] The challenges focused on additionality determination—which was eventually solved by referring to the consolidated additionality test, baseline lamp utilization, and the intensity of monitoring. Regulators criticized the assumption of unchanged usage patterns (UNFCCC 2005a) and required four distinct sampling groups of at least 100 households, two of which should include households not participating in the project. Two groups serve for determination of baseline and for project emissions (baseline and project sample groups), with

[4] An anonymous referee has criticized this as "self serving litany". However, we think that the narrative is valuable to understand the difficult interaction between methodology developer and CDM regulators.

[5] For a detailed description of the process see A. Michaelowa et al. (2007): The long and stony road of getting CFL distribution into the Clean Development Mechanism, in: Energy Manager, 1, 4, p. 23-26

another two serving to cross-check the results achieved (baseline and project cross-check groups). Utilization hours of each lamp in the sampling groups should be metered individually. Metering equipment, which can either be an electricity or a run-time meter, has to be attached to the lamp or the cable, not the socket, to prevent project participants that are involuntarily keeping the lamps distributed by the project.[6] A social lottery system should be introduced to provide a strong incentive for not leaving the sample groups. The regulators also prohibited any other CDM project replacing compact fluorescent lamps (CFLs) in households within the geographical area of the proposed project. Each household can receive a maximum of four lamps. Fused CFLs distributed by the project cannot be replaced.

The emission reduction is determined through the difference in absolute lighting energy use between the baseline sample group and the project sample group, multiplied by the grid emissions factor determined according to methodology ACM 0002 for electricity grids, taking into account technical distribution losses. If the electricity consumption of the baseline sample group is significantly higher than the consumption of the baseline cross-check group, the lighting energy use of the baseline sample group will be discounted accordingly. Analogously, project lighting use will be increased by a multiplier if the electricity consumption of the project sample group is significantly lower than the consumption of the project cross-check group. The conservative (=high) end of a 95% confidence interval of energy use across the sample group is used to define project energy use.

Moreover, a power correction factor has to be applied that takes into account that lamp electricity use depends on the actual grid voltage achieved. Monitoring information required includes household names, addresses, GPS coordinates and the name of the project area, the date of return of the incandescent lamp and of the distribution or sale of CFLs as well as the place and number of lamps found during spot checks in the household/in its living area and information on which lamps have been added or removed by the household since the last spot check. Scrapping of returned lamps has to be proven by an independent party.

The differences between the initial and final methodology design surprisingly were not due to differing interpretation of additionality between the methodology developer and the regulators, but due to fears of the regulators that behavioral changes of CFL users would lead to an increase of emissions not covered by the assumption that usage would remain constant. Moreover, regulators feared that CFLs would break down quickly under developing country conditions and thus requested thorough monitoring.

Pragmatic solution—adapting the small-scale methodology for real life

It is unlikely that the methodology AM 0046 will ever be applied due to the complexity of monitoring requirements. Even Perspectives as developer of the methodology is now using the small-scale methodology AMS II.C ("Demand-side energy efficiency activities for specific technologies"), as the threshold of 60 GWh annual savings is sufficiently high to make projects viable. This required substantial work on the small-scale methodology. The decision to develop the first CFL projects under small-scale methodology AMS II.C led to some disadvantages for project developer Osram, who had planned to distribute lamps to around 4 million households and on average two lamps per household, whereas now due to the small-scale project threshold, the number of participating households was limited to about 400,000 to 800,000 households depending on the number of CFLs distributed per household and the amount of CERs that can be generated by each distributed CFL. The first project targets about 700,000 households, which are registered customers of the power utility in the corresponding district and have an electricity grid connection. Households can substitute up to two incandescent lamps (general lighting services, GLS) in their home by CFLs provided through the project. Only GLS with wattages equal to or higher than 60 W will be replaced. The project CFLs will be put only in

[6] So far, no technology provider exists who would supply such measurement equipment off-the-shelf; equipment has to be developed from scratch. Estimates for the cost of the monitoring equipment for one lamp range from 10 to 30 €. A methodology submitted by the World Bank tried to avoid ex post monitoring by assuming usage hours, CFL lifetimes and specifying a 5% discount for autonomous penetration of CFLs. The free riding issue was to be addressed by making households answer the question whether they would have purchased the CFL without the subsidy, which was one of the main reasons of rejection by the EB (UNFCCC 2007).

places where GLS have been used before and where the lighting behavior is appropriate. The actual distribution will be carried out by pre-trained distribution teams visiting the project households "door-to-door".

At first glance, AMS II.C and its equation which needs to be applied for monitoring the resulting CO_2 reductions, seemed rather simple and straightforward. With just two pages compared to the 34 pages of the large-scale methodology AM0046, AMS II.C has been kept rather general. The baseline calculation is limited to the following equation:

$$E_B = \sum_i (n_i \cdot p_i \cdot o_i)$$

E_B annual energy baseline in kWh per year

Σ_i the sum over the group of i devices replaced (e.g. 40 W incandescent lamp, 5 hp motor), for which the replacement is operating during the year, implemented as part of the project.

n_i the number of devices of the group of i devices replaced (e.g., 40 W incandescent lamp, 5 hp motor) for which the replacement is operating during the year.

p_i the power of the devices of the group of i devices replaced (e.g. 40 W, 5 hp). In the case of a retrofit activity, "power" is the weighted average of the devices replaced. In the case of new installations, "power" is the weighted average of devices on the market.

o_i the average annual operating hours of the devices of the group of i devices replaced.

In addition, some rather general requirements address leakage effects. Only the number of lamps replaced and lamps installed, the weighted average power of the replaced lamps and the power of each lamp installed, the average annual operating hours of the replaced lamps and the same for the lamps installed need to be monitored. Regarding the "power" of the new lamps "nameplate data or bench tests of a sample of the units installed" are to be used and a sample of the lamps installed is to be metered "for their operating hours using run time meters".

While proceeding with gathering project information, developing the necessary documentation, attending the on-site validation in the host country together with the validator and the project developer, designing the monitoring plan and estimating emission reductions on behalf of the more detailed information) it became obvious that the alleged simplicity of AMS II.C has been rather deceptive. To adapt the methodology to the real-life project conditions and requirements raised during validation of the first project, the above equation and some additional issues needed to be substantiated while maintaining them conceptually. The result was a quite sophisticated monitoring concept consisting of 15 equations and 15 parameters to be monitored. The derivation of the parameter of operating hours, which are measured for the baseline (GLS) prior to the distribution in a number of representative sample households and for the project (CFL) continuously during the whole crediting period in a representative sample group was challenging. Osram faced the problem that the majority of parameters (average wattage, number of replaced and distributed lamps, operating hours), which will be only monitored during the actual project period, need to be estimated d. We did a market survey in the project location which had to be representative and traceable to fulfill the requirements of the validator. When distributing the lamps, household-specific data are recorded on one distribution form per household and the destruction of the replaced GLS is monitored. After the meters have been installed in the sampling group and metering has been done for are specified period, monitoring can be done for that monitoring period. It is also checked how many of the installed CFLs are in operation.

Due to the enormous amount of households that need to be visited and the even higher number of lamps need to be distributed, a highly sophisticated coordination plan for the distribution process is needed. It starts with finding the appropriate number of people taking part in the physical distribution. These people need a proper training, so that they can fill in the printed forms during distribution. Considering the number of households to be visited in sometimes not easily accessible areas of a developing country and the logistical effort that comes along with that, one of the major challenges related to the project type becomes rather clear. After several months of fine-tuning the baseline and monitoring approach, the first project was validated in spring 2008. After a request for review, the EB decided in October 2008 that the project could be registered with two minor corrections of the project documentation.

The application of the small-scale methodology showed that a short, seemingly simple methodology could not be used directly without substantial interpretive work, which would have been difficult without the experiences gathered in developing the large-scale methodology AM 0046. Again, the key challenges were related to selection of sampling groups and implementation of a monitoring concept.

How the programmatic approach could alleviate monitoring costs

Seeing the challenges in developing a small-scale project for CFL distribution, we would like to discuss whether the new option of CDM Programs of Activities (PoAs) alleviates these problems and could allow the roll-out of country-wide CFL distribution activities (see Hinostroza et al. 2007 for a generic assessment how PoAs could mobilize end-use energy efficiency). A PoA allows to submit an unlimited number of projects (CDM Program Activities, CPAs) during a 28-year period. The PoA coordinator has to collect and archive monitoring reports from all CPAs. A PoA can use small-scale methodologies without any limit on the size of the PoA, but have to use PoA-specific versions of the small-scale methodologies that account for leakage. The leakage rules essentially require independent monitoring of scrapping of replaced equipment. Due to the problems in applying AM 0046, a CFL PoA has to be based on the small-scale methodology AMS II.C. Theoretically, a PoA can substantially reduce monitoring costs due to the possibility to monitor only a sample of the CPAs. Moreover, a centralized approach to monitoring can reduce the costs for monitoring equipment, which would be procured in large numbers. Also, monitoring experts could be trained, which would avoid the haphazard approach to monitoring found in many CDM projects.

We describe the “CDM-based energy efficient lighting scheme called the ‘Bachat Lamp Yojana’ of Government of India” PoA currently under preparation in India, identify key risk factors and describe some solutions that were applied.

Key features of a CFL CDM distribution program in India

Lighting accounts for almost 20% of Indian total electricity demand and contributes almost fully to the peak load. In recent years, energy-efficient lamps have been introduced into the Indian market. However, penetration into households has been limited, largely because of the high initial costs of CFLs. The price of 11 W to 18 W CFLs is still in the Rs. 80–150 range (€ 1.2–2.3) whereas the 40 to 100 W GLSs cost Rs. 10–15 (€ 0.15–0.23).[7] It is estimated that about 400 million light points in India today are lighted by incandescent lamps; their replacement by CFLs would lead to a reduction of over 10,000 MW in electricity demand in a country which currently faces a shortage of up to 12.3% (Jain et al. 2007).

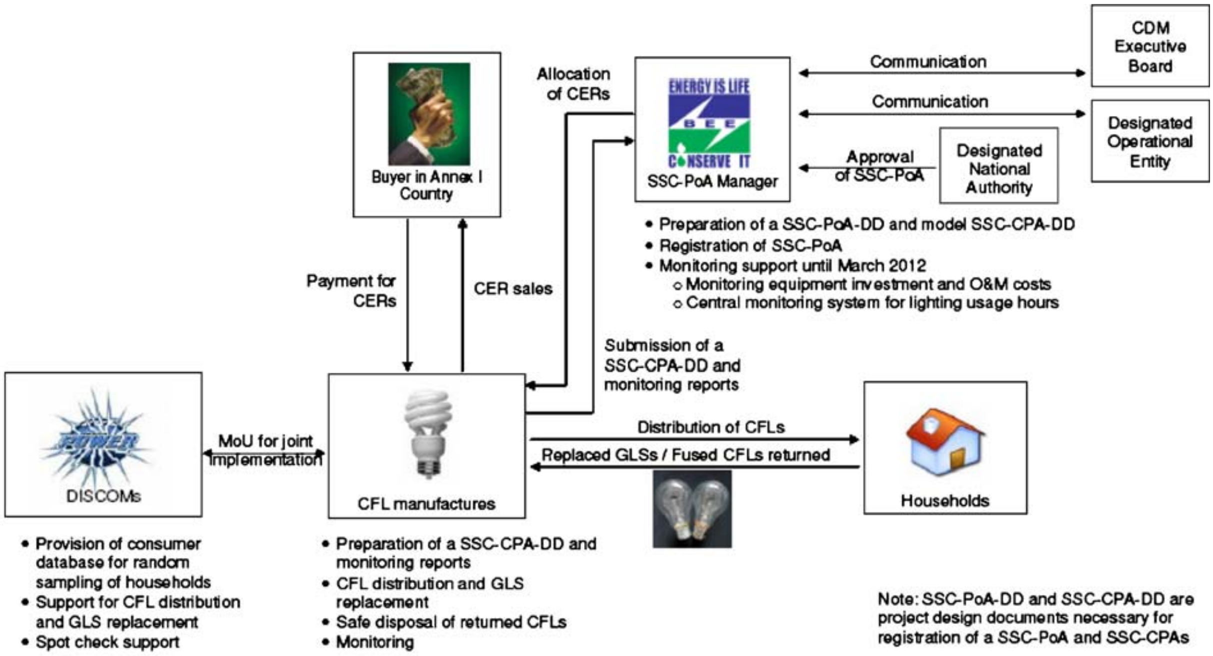
The PoA aims to accelerate penetration of CFLs in the residential sector by offering CFLs at subsidized prices. A public–private partnership among the Government of India, private sector CFL manufacturers, and state-level power distribution companies (DISCOMs) provides the framework to distribute CFLs at about Rs. 10–15 per piece and recover the balance of costs from future CER revenues. The PoA boundary is set as the entire political boundary of India. Grid-connected households in an area covered by a CPA are eligible for participating in the CPA. They receive CFLs in return of currently used and functioning GLSs. The returned incandescent light lamps are to be destroyed in order to avoid leakage (e.g. via resale of GLSs). The CFLs are to be distributed directly at each household and/or at dedicated distribution/collection points.

The Bureau of Energy Efficiency (BEE), a statutory body set up under the Energy Conservation Act, 2001 by the Government of India, will coordinate the PoA and support the CFL manufacturers in implementing CPAs in various states through services of DISCOMs. The development of the PoA is a voluntary action on the part of BEE and it would not seek any commercial revenues from PoA implementation. On the other hand, BEE will take the responsibility of monitoring lighting usage hours in randomly selected households in each CPA until March 2012. The key actors and their responsibilities in the SSC-PoA are summarized in Fig. 5.

Baseline and monitoring approaches

The PoA is based on AMS-II.C. Since it is not cost effective to monitor every single CFL distributed to the households, statistical treatment is indispensable. The PoA calculates lighting usage hours and the

[7] 1.00 Rs.=€ 0.015 (on 13 June 2008). FXHistory®: historical currency exchange rates. http://www.oanda.com/convert/fxhistory.



Source: Authors

Fig. 5 Organizational overview of the SSC-PoA

number of functioning CFLs by monitoring randomly sampled households. The monitoring equipment allows for a centralized remote monitoring by transmitting the lighting usage hour data to the central server. However, this technology is not available "off-the shelf". BEE had to do two rounds of public tendering before it received a bid that conformed to the tender specifications. The equipment is costly as it contains several high-tech features. It remains unclear how reliable it will be under Indian conditions. Failure of monitoring equipment will immediately lead to a loss of CERs.

Another key variable, the number of functioning CFLs is to be estimated based on a spot check of randomly selected households. The spot check will be conducted at the households at the end of each monitoring interval in order to monitor any change of number in the distributed CFLs in operation. The periodicity of the spot check is planned to be every 6 months. The spot check is supported by DISCOMs by combining it with their regular electricity consumption metering at their customer households (i.e., the grid-connected households).

Given the power rating of replaced lamps and distributed CFLs known at the distribution of CFLs and replacement of the baseline lamps, the estimated lighting usage hours and number of functioning CFLs determine the energy savings achieved by the PoA. The energy savings are to be multiplied by the relevant grid emission factor to calculate the emission reductions. As a consequence of the sampling approach, the emission reductions are to be adjusted by sampling errors. The smaller sample size leads to a higher margin of error (although it reduces transaction costs). Therefore, an important trade-off exists between the sample size (i.e., transaction costs) and CER volume. Careful contemplation of the optimal sample size is necessary to maximize CER volume under the transaction costs constraint.

As of May 2008, 18 CFL manufactures and 14 states have agreed to participate in the PoA (Pradhan 2008). However, without the considerable amount of support given by the government, the program would have probably been unable to attract these CFL manufacturers and states. Given the large scale, this PoA should be able to mobilize substantial savings in monitoring costs. Whether the PoA will be able to deliver the centralized monitoring services and whether the selected equipment is sufficiently robust, remains to be seen. So far, several obstacles in international rules for PoAs, particularly the unlimited liability of the validator, have stalled progress.

Deemed savings—the way forward?

As shown in the previous sections, the currently available approved methodologies for demand-side energy efficiency projects are complex and involve high monitoring costs and risks. These might be reduced by PoAs but the proof that PoAs bring down monitoring costs substantially through centralized sampling and procurement of monitoring equipment has not yet been made. Therefore, an alternative baseline and monitoring approach has been proposed to enable end-use energy efficiency improvement to realize its full potential under the CDM. As a promising candidate for such an alternative approach, this section examines the deemed savings approach commonly applied in CFL program evaluation outside the CDM regime. It further analyzes the recently approved CDM methodology based on the deemed savings approach.

Deemed savings in CFL program evaluation outside of the CDM

CFL programs are a well-recognized and desired demand-side management (DSM) option and have been implemented in industrialized countries for several decades. As a DSM program, the evaluation of program impact (e.g., energy savings, demand savings) has been considered of the essence for improvement and accountability of the program. The most common CFL program evaluation method employed outside the CDM regime is the deemed savings approach. It is the most widely used approach to quantify energy savings from DSM programs that promote the uptake of small electrical end-use equipment dispersed in households, commercial buildings or industry (Arquit Niederberger et al. 2007). The approach is one of the three main approaches to determine gross energy savings, besides measurement and verification (M&V) approach as used AMS-II.C and AM0046 and described above, and gross billing analysis.[8] With the deemed savings approach, gross energy savings are estimated based on stipulated values, which come from historical savings values of typical projects. The savings determined for a sample of projects are applied to all the projects in the program. However, with the use of deemed savings there are no or very limited measurement activities and only the installation and operation of measures is verified. This approach is only valid for projects with fixed operating conditions and well-known, documented stipulation values (e.g., energy-efficient lighting retrofit projects with well understood operating hours). The gross energy savings are determined by multiplying the number of installed measures by the estimated (or deemed) savings per measure (NAPEE NAPEE, National Action Plan for Energy Efficiency, 2007).

The gross energy savings are adjusted by a net-to-gross (NTG) ratio to determine net energy savings by the program.[9] The NTG ratio is an indicator of the share of the program's gross energy savings that can be properly attributed to the program's influence, above and beyond what would have occurred without the program. The ratio consists of the two main elements: (a) free ridership, and (b) spillover. Free ridership refers to the portion of energy savings that participants would have achieved in the absence of the program through their own initiatives and expenditures. Spillover refers to the program-induced adoption of measures by non-participants and participants who did not claim financial or technical assistance for additional installations of measures supported by the program (NAPEE, National Action Plan for Energy Efficiency, 2007). This influence is a

[8] Gross billing analysis approach conducts statistical analyses on the energy usage data (typically collected from the meter data reported on utility bills) for all or most of the participants and possibly non-participants in the program. The M&V approach is the most common approach used for program involving non-residential facilities, retrofit, or new construction, in which a wide variety of factors determine savings and when individual facility savings values are desired. Gross billing analysis is primarily used for residential program with relatively homogenous participants and measures, when project-specific analyses are not required or practical (NAPEE 2007).

[9] For further details of the NTG estimation methods, refer to e.g. TecMarket Works (2004) and Rathbun et al. (2003).

combination of two types of spillover: (a) outside-project spillover—participants purchased additional CFLs through other outlets, and (b) non-participant spillover - non-participants were induced to purchase CFLs because of suggestions from participants, greater availability in the marketplace, etc. (Skumatz and Howlett 2006). The effect of free ridership and spillover is aggregated to the NTG ratio, which can be mathematically expressed as follows:

$$\mathrm{NTG} = (1 - \mathrm{FR}) \times (1 + \mathrm{SO})$$

where:

FR is the share of free ridership (fraction); and
SO is the share of spillover (fraction).

There are four main approaches to determine the NTG ratio: (a) self-reporting survey,[10] (b) enhanced self-reporting surveys,[11] (c) econometric methods,[12] and (d) stipulated (or deemed) NTG ratio[13] (NAPEE, National Action Plan for Energy Efficiency, 2007). The first two are survey-based methods, which estimate free ridership and spillover by asking participants directly a series of questions on what they would have done in the absence of the program. The survey method is the most straightforward method of the NTG ratio estimation, and one of the lowest cost methods. It does, however, have its disadvantages in potential bias and with accuracy (TecMarket Works 2004). On the other hand, the econometric methods are sometimes considered the most accurate type of NTG estimation method. They are preferred in situations where there are enough participants and comparable non-participants, and when the program is large enough to justify expense of the method (TecMarket Works 2004). Lastly, the application of a deemed NTG ratio is naturally the simplest and lowest cost approach if such ratio is already available.

[10] Information is reported by participants and non-participants, without independent verification or review.

[11] The self-reporting surveys are combined with interviews and independent documentation review and analysis. They may also include analysis of market-based sales data.

[12] Statistical models are used to compare participant and non-participant energy and demand patterns. These models often include survey inputs and other non-program-related factors such as weather and energy costs.

[13] A NTG ratio is estimated using information available from evaluation of similar program.

Finally, the net energy savings can be determined by multiplying the gross energy savings by the NTG ratio.

As shown above, the choice of program impact evaluation methods faces a trade-off between accuracy and evaluation costs. It is hence important to strike a balance between perfect and good enough evaluation methods. In the right circumstances, a deemed savings methodology could be as robust as a methodology based on monitoring, particularly in advanced developing countries where the behavioral impact of lighting efficiency increase can be assessed more easily than in the context of a low-income country.

Reduction of M&V requirements through the new deemed saving methodology

In August 2008, a new small-scale methodology AMS II.J “Demand-side activities for efficient lighting technologies” was approved by the EB, based on a submission by the World Bank. After the failure of their large-scale methodology submission and the realization that AM 0046 was too cumbersome for real-life application, the World Bank wanted to press for a “revolutionary” approach. The methodology essentially follows the deemed savings approach employed by the existing DSM programs. In line with the common practice in the deemed savings approach, the original submission of the methodology (Arquit Niederberger et al. 2007) attempted to use default values for lighting usage hours, baseline technology type, and power rating of the baseline equipment. However, the small-scale working group (SSC WG) of the CDM EB requested an ex-ante representative sample survey on AMS-II.C-like monitoring items (i.e., lighting usage hours, type of baseline technology and power rating of the baseline equipment). Moreover, potential rebound effects caused by the project should be taken into account. Furthermore, the NTG ratio should be updated at least once every 3 years using a representative sample of lamps.[14] The revised submission clarified that the

[14] Such update may make sense for the purpose of checking functionality of the CFLs installed. However, the methodology would likely be unworkable if the NTG ratio was really to be updated. The NTG ratio in the original submission included not only free ridership and spillover issues, but also permanence of the CFL usage. This has likely led to the SSC WG request for the NTG ratio update.

Table 1 CER volume of the CFL project in Visakhapatnam using methodology AMS II.C and II.J

Methodology	Daily operation	T&D loss	NTG ratio	Pre-project CFL penetration ratio	CERs in year 1
AMS II.C	5.1 h	0	1	n.a., de facto 1	39,816
AMS II.J	3.5 h	0.1	0.95	0.93	27,198

The project distributes 0.63 million CFLs, which have 45 W less than the replaced GLS. The applied grid emissions factor is 850 g CO_2/kWh

question whether a CFL installed by the project was still working is to be covered by a "base survival factor", which is calculated ex-ante based on manufacturer's specifications. It is updated ex post, at least once every 3 years to reflect the actual survival rate of distributed CFLs. Furthermore, it clarified that the NTG ratio was to take into account only free ridership and spillover effects (but not, e.g., the permanence of the CFL use), and not to be updated ex post. An ex ante survey as per the SSC WG recommendation was included. While in its recommendation on the revised submission the SSC WG had proposed to apply 3 h as daily default maximum use of CFLs and a NTG ratio of 0.85, the EB increased the daily use to 3.5 h and the NTG ratio to 0.95. However, it specified stringent applicability conditions, such as the requirement to charge a price for the CFL[15] and document measures to exchange defective CFLs. T&D losses are taken into account, but capped at 10%.[16] The crediting period ends at the rated lifetime of the CFLs. At the latest, 1 year after installation of all CFLs, the number of operational CFLs has to be determined by a survey. Follow-up surveys are to be done at least every 3 years to determine actual CFL failure rates. The minimum sample size for the surveys is 100. In case of PoAs, the ex ante survey has to measure the pre-project rate of CFL use and the CERs are discounted by that rate. Moreover, in the first version of the approved methodology for cold areas increased heating due to the reduction of heat generation from lighting had to be calculated as leakage!

To demonstrate application of methodology AMS II.J, the parameters of the Osram project in India (Osram AG, 2008) are used in Table 1, assuming it would be done under a PoA

[15] This requirement was scrapped in the second version of November 2008.

[16] The cap was changed into a default factor in the second version; losses can be higher if "accurate and reliable" data are available

Assuming that the rated lifetime of the lamp reaches 10 years, the deemed savings methodology thus leads to a reduction of CER levels by over 30%. The reduced monitoring costs thus come at a heavy price, as long as daily utilization hours are high and the project belongs to a PoA.

With regards to expansion to project types other than CFL distribution, the deemed savings approach requires special care when performance characteristics and use conditions of a measure are not well known or consistent (NAPEE, National Action Plan for Energy Efficiency, 2007). For example, measures with high variation in operating use or sensitive to changes in exogenous factors such as weather are likely to require adjustments in the estimation (Arquit Niederberger et al. 2007). Importantly, the deemed savings approach can be used together with some monitoring of one or two key parameters. For instance, in a high-efficiency motor program, actual operating hours could be monitored over a full work cycle (NAPEE, National Action Plan for Energy Efficiency, 2007). Such combination of the deemed savings and M&V concepts could increase practicability of a CDM methodology while maintaining the necessary degree of the environmental integrity. In order to strike a balance between accuracy in emission reduction calculation and practicability of the methodology application, it is important to elaborate what parameters can be deemed and what not for specific project types.

The deemed savings methodology has relaxed the heavy monitoring requirements of AMS-II.C and AM0046 with regards to CFL use duration, and hence is an important breakthrough. The EB accepted the following parameters as "deemed" for CFL programs: (a) lighting usage hours, (b) type of baseline technology, (c) power rating of the baseline equipment. However, these parameter values shall be derived from ex-ante survey results specific to the project location and regarding usage hours, a very stringent cap has been defined. On the other hand, permanence of CFL usage was not accepted as a deemed parameter, which reflects the view that unpredictable grid characteristics in developing countries will have strongly differing impacts on lifetimes of project CFLs.

Conclusions

End-use energy efficiency improvement is one of the largest greenhouse gas reduction options in developing countries. This project type can be considered to be highly sustainable, because it will lead to reduced consumption of fossil fuel for electricity generation and thus reduce local pollutants such as NO_x and SO_2. Moreover, it promotes technology transfer, contributes to poverty alleviation by significantly reducing household expenditure on electricity bills, increases energy services in countries which face considerable power outages, and leads to at least temporary employment of local people (e.g., NGOs that help distributing the appliances). Particularly in rapidly industrializing countries with a strong urbanization trend, lock-in of inefficient technologies in households and service sectors has to be prevented. Despite the high theoretical potential and urgency of end-use efficiency improvement, the CDM has not been able to mobilize a relevant volume of such projects; efficiency improvement in the household and service sectors covers less than 1% of the volume of CERs. The case of projects distributing CFLs shows that the main hurdle is the determination of the baseline and monitoring of the emission reductions. As the methodologies that have been approved after a lengthy struggle between project developers and regulators all require cumbersome monitoring for a significant sample of the recipients of CFLs, the approach of programmatic CDM could overcome problems of the project-specific CDM, as it allow to verify only a subset of the projects implemented under the program. This would reduce monitoring costs substantially. Moreover, a coordinated procurement of monitoring equipment could reduce equipment cost. Central implementation of monitoring would also allow to train expert staff and to avoid problems with the verifiers that plague many CDM projects.

Recently, a "deemed savings" methodology was approved that reduces monitoring requirements. It however still contains monitoring requirements such as ex-ante surveys at the project location to determine lighting usage, types of baseline technology and their power ratings as well as of the survival rate of CFLs. The methodology generates significantly less CERs than the other methodologies based on monitoring due to a very conservative assumption on average daily utilization of CFLs and the need to deduct baseline penetration of CFLs.

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References

Arquit Niederberger, A. (2008). Scaling up energy efficiency under the CDM. In K. Holm Olsen & J. Fenhann (Eds.), *A reformed CDM, including new mechanisms for sustainable development* (pp. 127–145). Copenhagen: UNEP Risø Centre.

Arquit Niederberger, A., Limaye, D., Brunner, C. (2007). Demand-side programs to promote high-efficiency electrical end-use technologies using deemed savings. Washington D. C.: The World Bank Carbon Finance Unit. http://cdm.unfccc.int/methodologies/SSCmethodologies/Clarifications/index.html. Accessed 13 June 2008.

Barker, T., Bashmakov, I., Bernstein, L., Bogner, J., Bosch, P., Dave, R., et al. (2007). Technical summary. In B. Metz, O. Davidson, P. Bosch, R. Dave & L. Meyer (Eds.), *Climate change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 26–93). Cambridge: Cambridge University Press.

Gupta, S., Tirpak, D., Burger, N., Gupta, J., Höhne, N., Boncheva, A., et al. (2007). Policies, instruments and co-operative arrangements. In B. Metz, O. Davidson, P. Bosch, R. Dave & L. Meyer (Eds.), *Climate change 2007: mitigation. Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change* (pp. 746–807). Cambridge: Cambridge University Press.

Hayashi, D., & Krey, M. (2007). Assessment of clean development mechanism potential of large-scale energy efficiency measures in heavy industries. *Energy, 32*, 1917–1931. doi:10.1016/j.energy.2007.03.003.

Hayashi, D., & Michaelowa, A.(2007): Lessons from submission and approval process of large-scale energy efficiency CDM methodologies. HWWI Research Paper No.4-11, Hamburg

Hinostroza, M., Cheng, C., Zhu, X., & Fenhann, J. (2007). *Potentials and barriers for end-use energy efficiency under programmatic CDM, Working Paper No. 3, CD4CDM Working Paper Series*. Roskilde: URC.

Greenpeace International. (1998). *Making the clean development mechanism clean and green*. Amsterdam: Greenpeace.

Jain, M., Gaba, V., & Srivastava, L. (2007). *Managing power demand: a case study of the residential sector in Delhi*. New Delhi: The Energy and Resources Institute.

Levine, M., Urge-Vorsatz, D., Blok, K., Geng, L., Harvey, D., Lang, S., et al. (2007). Residential and commercial buildings. In B. Metz, O. Davidson, P. Bosch, R. Dave & L. Meyer (Eds.), *Climate Change 2007: mitigation. Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change* (pp. 387–446). Cambridge: Cambridge University Press.

Michaelowa, A., & Jotzo, F. (2005). Transaction costs, institutional rigidities and the size of the clean development mechanism. *Energy Policy, 33*, 511–523. doi:10.1016/j.enpol.2003.08.016.

Michaelowa, A., Gagnon-Lebrun, F., Hayashi, D., Salgado Flores, L., Crete, P., & Krey, M. (2007). *Understanding CDM methodologies*. London: DEFRA.

Müller-Pelzer, F., & Michaelowa, A. (2005). *Lessons from the submission and approval process of energy-efficiency CDM baseline and monitoring methodologies, HWWI-Research Paper 1*. Hamburg: HWWI.

NAPEE (National Action Plan for Energy Efficiency). (2007). *Model energy efficiency program impact evaluation guide*. Washington D.C: U.S. Environmental Protection Agency.

Osram AG. (2008). Visakhapatnam (India) OSRAM CFL distribution CDM Project, Version Number: 05, download at http://cdm.unfccc.int/Projects/DB/TUEV-SUED1206629154.85/ReviewInitialComments/5HZCBC52WEQG6RTDKUQ2I0C1D2PX4N

Pradhan, G. (2008). India: Growing energy needs and mitigation options. New Delhi: Ministry of Power, Government of India. http://www.oecd.org/dataoecd/39/15/40633690.pdf. Accessed 13 June 2008.

Rathbun, P., Sabo, C., & Zent, B. (2003). *National grid, NSTAR electric, Northeast utilities, Unitil, Cape light compact: Standardized methods for free-ridership and spillover evaluation—Task 5 final report (revised)*. Wisconsin: PA Government Services.

Rentz, H. (1998). Joint implementation and the question of additionality–a proposal for a pragmatic approach to identify possible Joint Implementation projects. *Energy Policy, 4*, 275–279. doi:10.1016/S0301-4215(97)00155-9.

Skumatz, L., & Howlett, O. (2006). *Finding and "gaps" in CFL evaluation research: review of the existing literature*. London: International Energy Efficiency in Domestic Appliances & Lighting Conference.

Spalding-Fecher, R. (2008). *Analysis of demand side energy efficiency baseline and monitoring methodologies, Presentation at Fifth CDM Joint Coordination Workshop*. Bonn: Econ.

UNFCCC. (2005a). *Ghana efficient lighting retrofit project, CDM: proposed new methodology assessment form*. Bonn: UNFCCC.

UNFCCC.(2005b). Decision 3/CMP.1, Montreal: UNFCCC.

UNFCCC.(2007). CDM: Proposed New Methodology. Meth Panel recommendation to the Executive Board, F-CDM-NMmp ver 07.1 - NM0157-rev, Bonn: UNFCCC

URC.(2008). CDM pipeline, version May 1, http://www.cdmpipeline.org. Accessed October 2, 2008

Works, Tec Market. (2004). *The California evaluation framework. Prepared for the California Public Utilities Commission*. Oregon: TecMarket.